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TECHNICAL REPORT ARLCD-TR-78034

A GUIDE TO SENSOR SELECTION

SUSANNE J. BERNHARDT

SEPTEMBER 1978

US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
LARGE CALIBER
WEAPON SYSTEMS LABORATORY
DOVER, NEW JERSEY

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This report was conducted under Contract DAAA21-76-C-0123. EMX Engineering, Cedar Grove, NJ, designed and fabricated the sensor display control panel under the guidance of the Large Caliber Weapon Systems Lab of ARRADCOM, Dover, NJ.

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cont to p. 1

A display panel was fabricated which meets the following specifications:

(1) Unit is self-contained;

(2) The compatability of electronic and pneumatic technology is demonstrated,

and (3) The control panel sensors are evenly divided between electronic and pneumatic devices with the ability to add auxiliary sensors from external sources as may be required.

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INTRODUCTION

It was the intent of this effort to collect, categorize, and compare the sensing hardware available to industry and applicable to the Department of the Army's Plant Modernization and Expansion Program, in order to present to design and management personnel an organized methodology by which to accomplish the hardware selection process. The purpose of this display panel is to demonstrate a representative sample of sensors available on the market today and show their advantages and disadvantages. → (cont on p 1473 A)

GENERAL SYSTEM DESCRIPTION

Under Contract DAAA21-76-C-0123, EMX Engineering designed and fabricated a display panel which meets the following specifications:

1. The entire display system is self-contained.

2. The control panel demonstrates the compatability of electronic and pneumatic technology.

3. The control panel and sensors are evenly divided between electronic and pneumatic devices with the ability to add auxiliary sensors from external sources as may be required.

The entire system is housed in a steel container (fig. 1) with a removable top. Upon removal of the top, the control panel, all of the sensors, and a rotating target plate are visible (fig. 2). When facing the control panel, the stationary sensor array is as follows, starting with sensor No. 1 (which is to the left of the control panel):

A. ELECTRICAL

(1) Eddy current sensor
(2) Capacitive sensor
(3) Magnetic switch
(4) Infra-red retro reflector
(5) Hall effect sensor

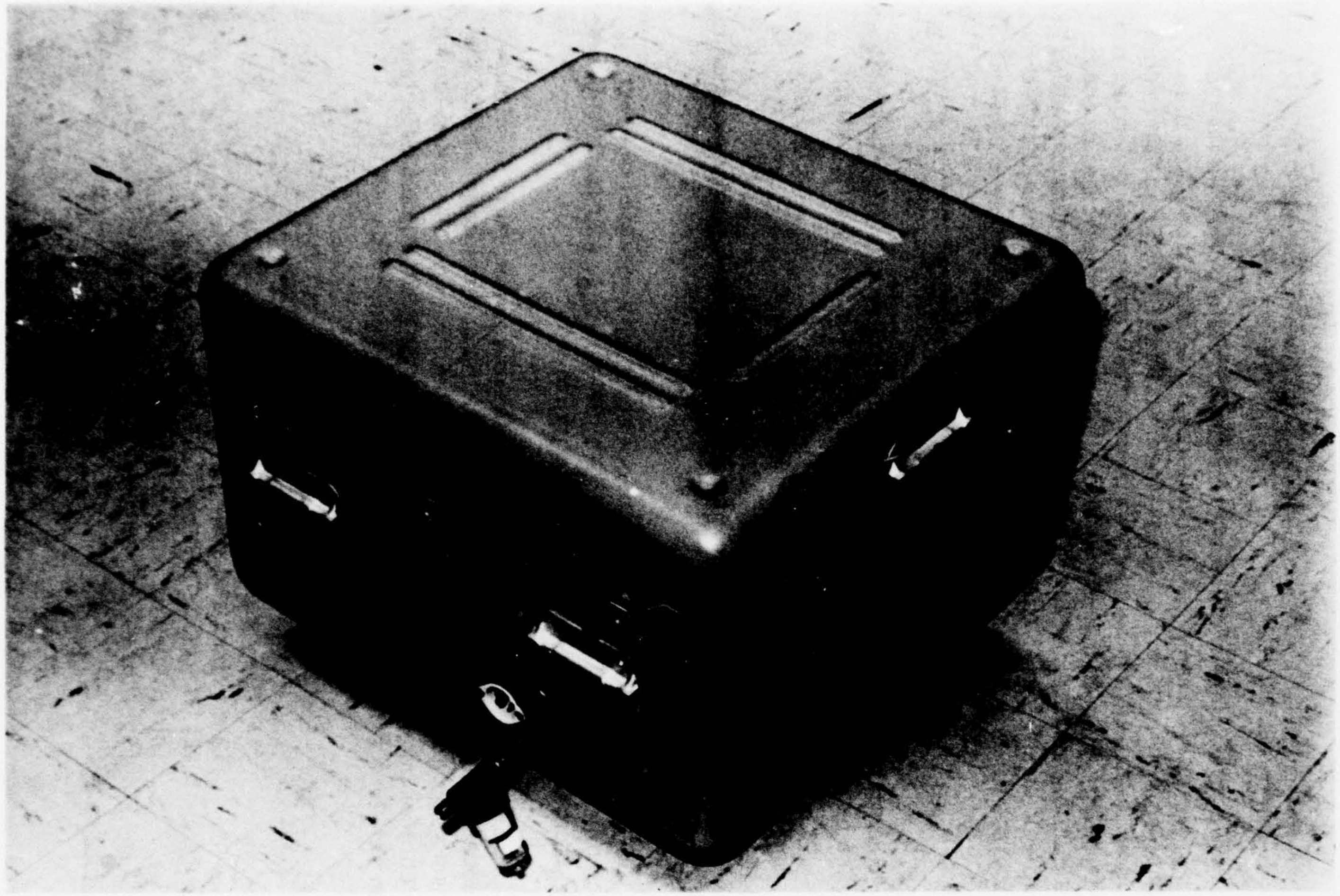

Figure 1. Sensor display control panel.

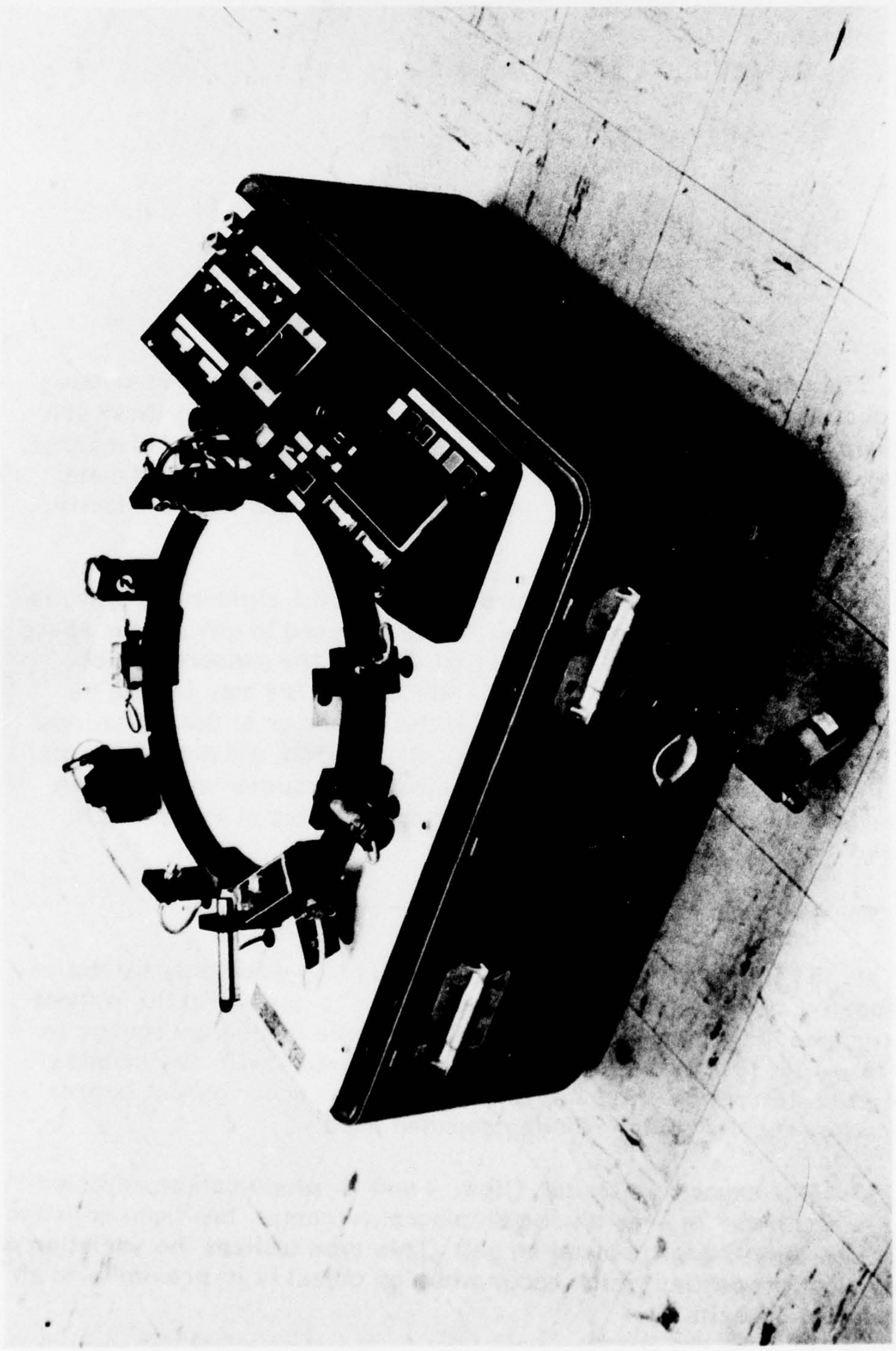

Figure 2. Sensor display control panel with lid off.

B. FLUIDIC

(6) Acoustic ear sensor
(7) Pneumatic limit valve
(8) Proximity sensor
(9) Whisker valve sensor
(10) Double interruptible jet sensor

ROTARY TABLE AND SENSORS

The rotary table is capable of carrying several types of sensing targets which are included with the unit (fig. 3). Among these are a plain ferrous metal target, a metal target with an imbedded magnet, a mechanical actuator for tripping the limit valve, a modified metal target to ensure triggering of the eddy current sensor, and, lastly, several plastic targets.

Immediately behind the control panel, on the right-hand side, is a rheostat control (speed control), which is used to govern the speed of the rotary target table. Notice that some of the sensors do not detect the targets moving at a moderate rate. This may be due to either the inherent characteristics of the sensor or to the limitations of the detection and read-out circuits chosen from the display panel. The proximity sensor will drive the electrical counter at very high speeds; whereas, the pneumatic counter saturates at a rate much lower than the sensor capability.

The sensors have been set to trigger as follows:

1. The eddy current sensor (fig. 4) is triggered only by the elongated metal target which has been sized to pass directly in front of the face of the sensor. This type uses radio frequency energy in to 10^7 to 10^{12} Hz frequency range which interacts with any metallic object within range of the sensing head. The sensor output is produced by the disruption of this projected field.

2. The capacitive sensor (figs. 4 and 5) which can be adjusted to sense any material over a wide displacement range, has been adjusted to sense only the large metal target. This type utilizes the variation of electrical properties which occur when an object is in proximity to an electrical capacitator.

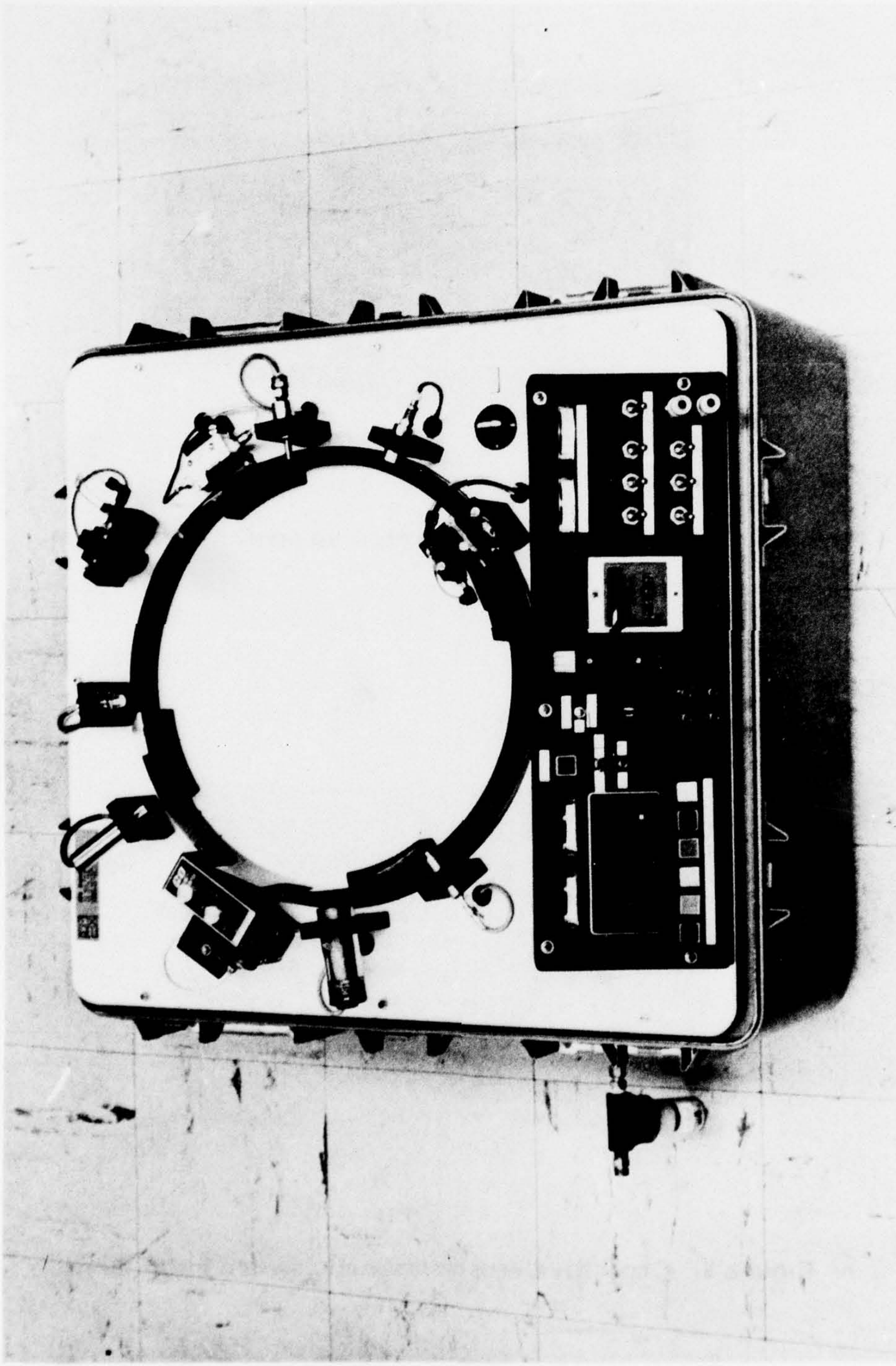

Figure 3. Rotary table and control panel.

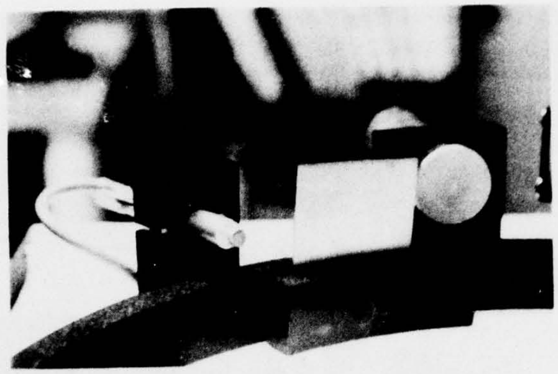

Figure 4. Eddy current sensor capacitive sensor metal target (large).

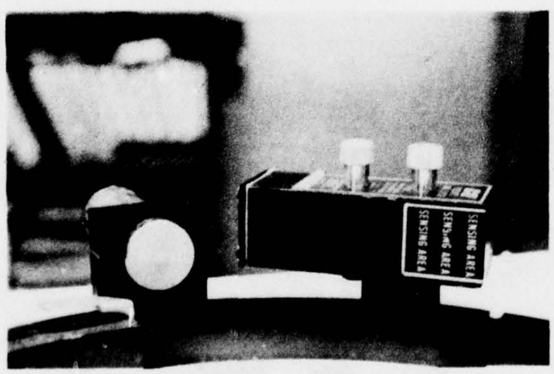

Figure 5. Capacitive sensor magnetic switch metal target.

3. The magnetic switch (fig. 5) is capable of sensing on the large ferrous metal target. This type utilizes either the disruption of a magnetic field, the actual magnetic attraction produced when a magnetic metal object is in close proximity to the sensor head, or the Hall effect.

4. The infra-red sensor (fig. 6) can be set up to detect almost any target. This type utilizes beams of light (either visible or invisible) as a sensing medium.

5. The Hall effect sensor (figs. 6 and 7) is triggered only by the south pole of the small magnet target. Hall effect sensors operate on the principle that the presence of a magnetic field causes a voltage (Hall voltage) to be produced across the edges of a current carrying, semiconductor chip. No Hall voltage is generated in the absence of a magnetic field. However, as a magnet is brought closer to the semiconductor chip or moved further away from it, the Hall voltage will increase or decrease proportionally.

6. The acoustic ear sensor (figs. 7 and 8) in the reflex mode reflects off of any target in its detection cone, and, therefore, reacts to all solid targets. This is a unique fluidic device which both generates and is sensitive to an acoustic energy signal. It is similar, in principle, to optical types of electronic sensors.

7. The pneumatic limit valve (figs. 7 and 9) is set to be triggered by the metal tab which contacts it. A mechanical actuator, such as a button or level arm, is attached to one of the valve types. The actuator moves the valve mechanism when an object pushes the actuator with enough force to overcome the valve return spring and internal friction. When the object passes, the valve returns to its original state.

8. The fluidic proximity sensor (figs. 10, 11, 12) is triggered by any solid target which passes within 0.188 inch (4.78 mm) of its face. The proximity sensor utilizes a form factor produced by a flowing gas and can sense a disturbance to this flow field when some object approaches the source of flow. Contact is not required.

9. The fluidic whisker valve sensor (figs. 12, 13, 14) is triggered by contact with any solid object. This type of sensor utilizes the actual physical movement resulting from contact with the sensed object. The resulting movement can be sensed via a number of mechanical-to-electrical transducers.

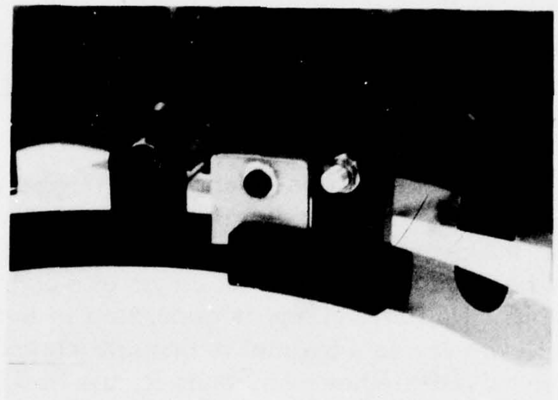

Figure 6. Infra-red retro reflective sensor Hall effect sensor metal target with magnet plastic target.

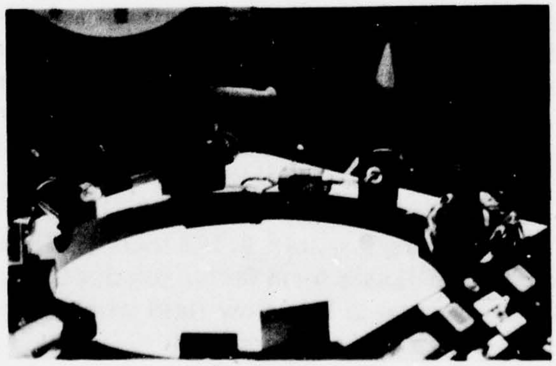

Figure 7. Hall effect sensor acoustic sensor pneumatic limit valve.

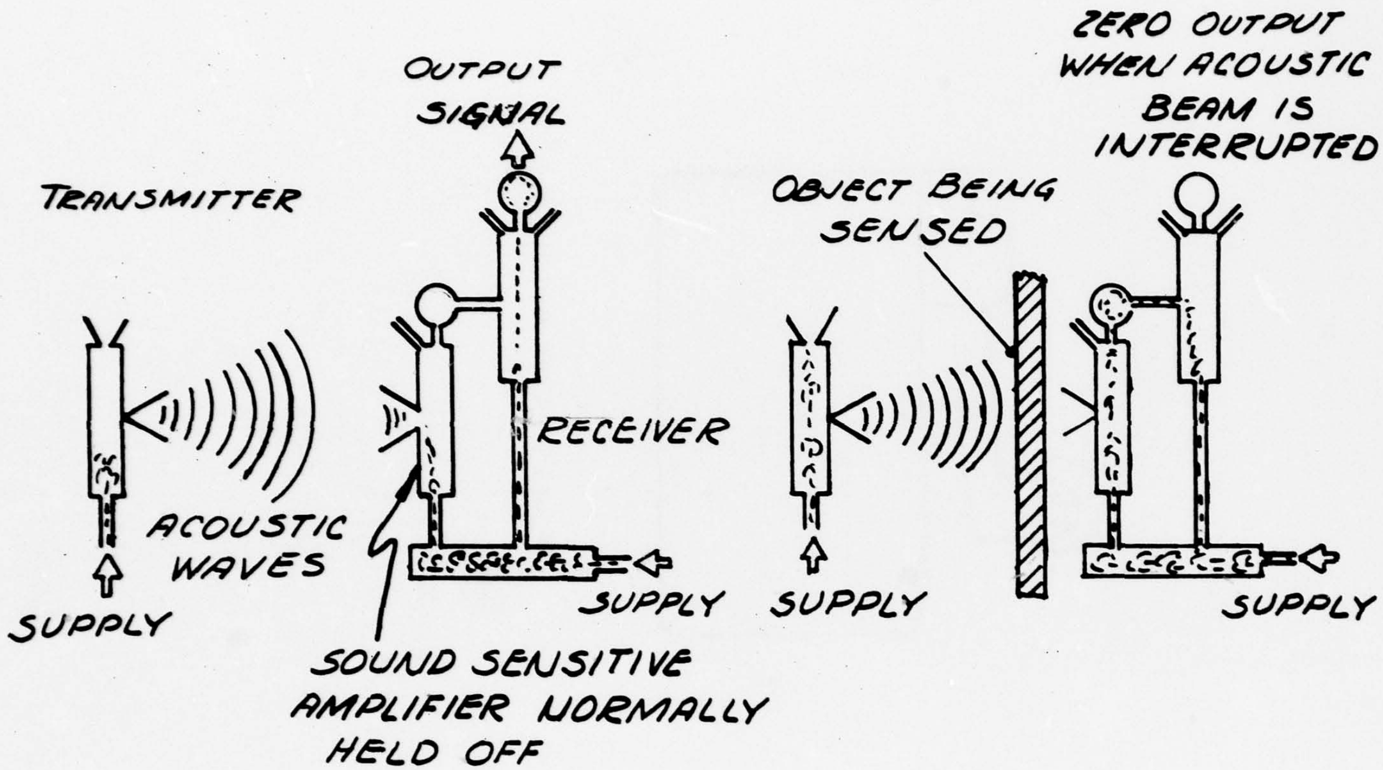

Figure 8. Acoustic sensing.

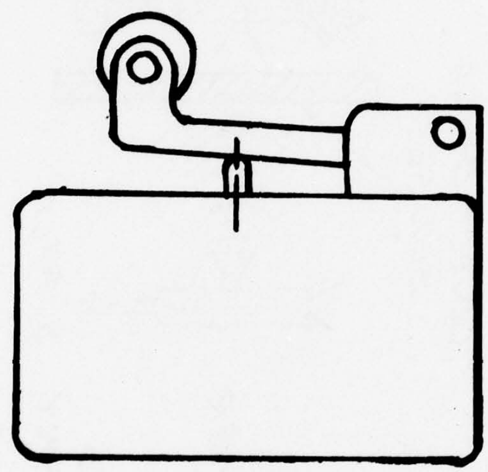

Figure 9. Limit switch.

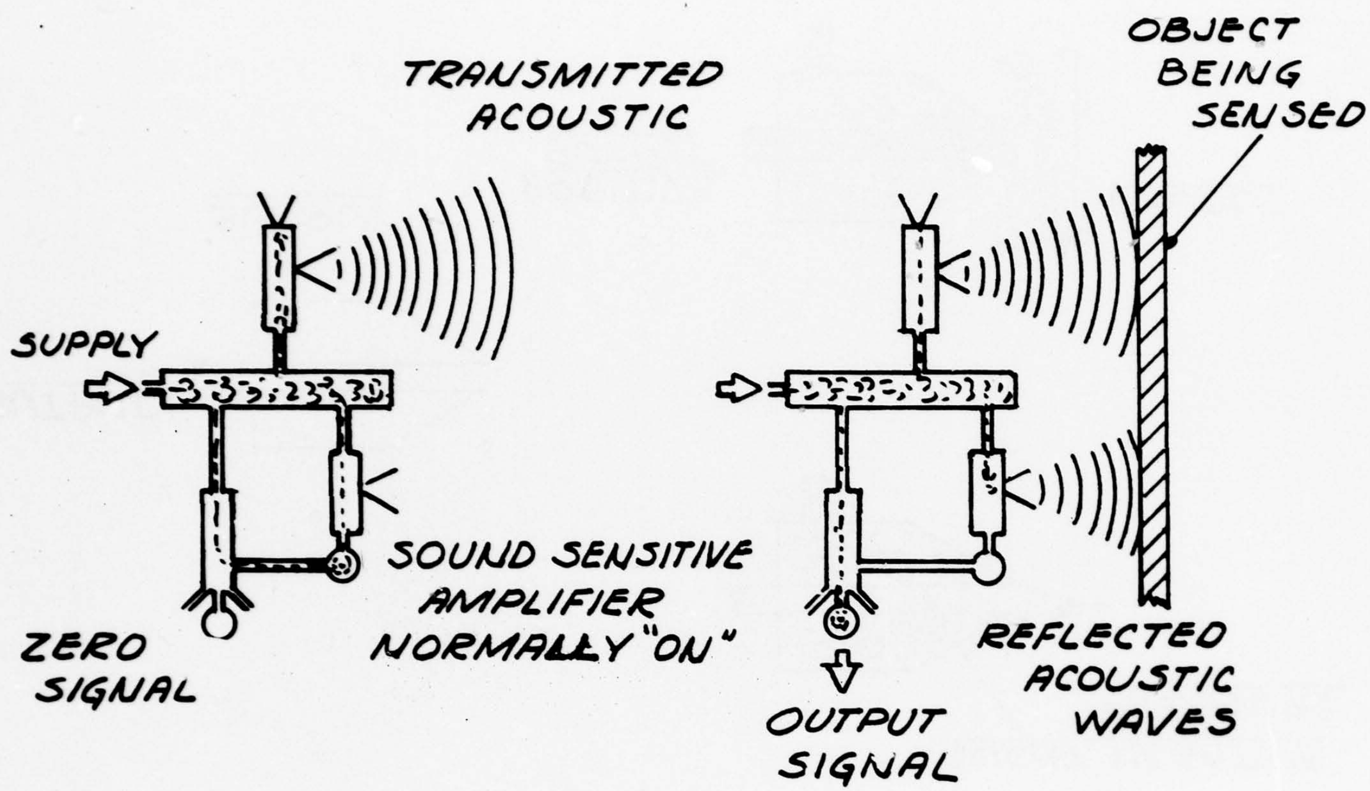

Figure 10. Fluidic ear.

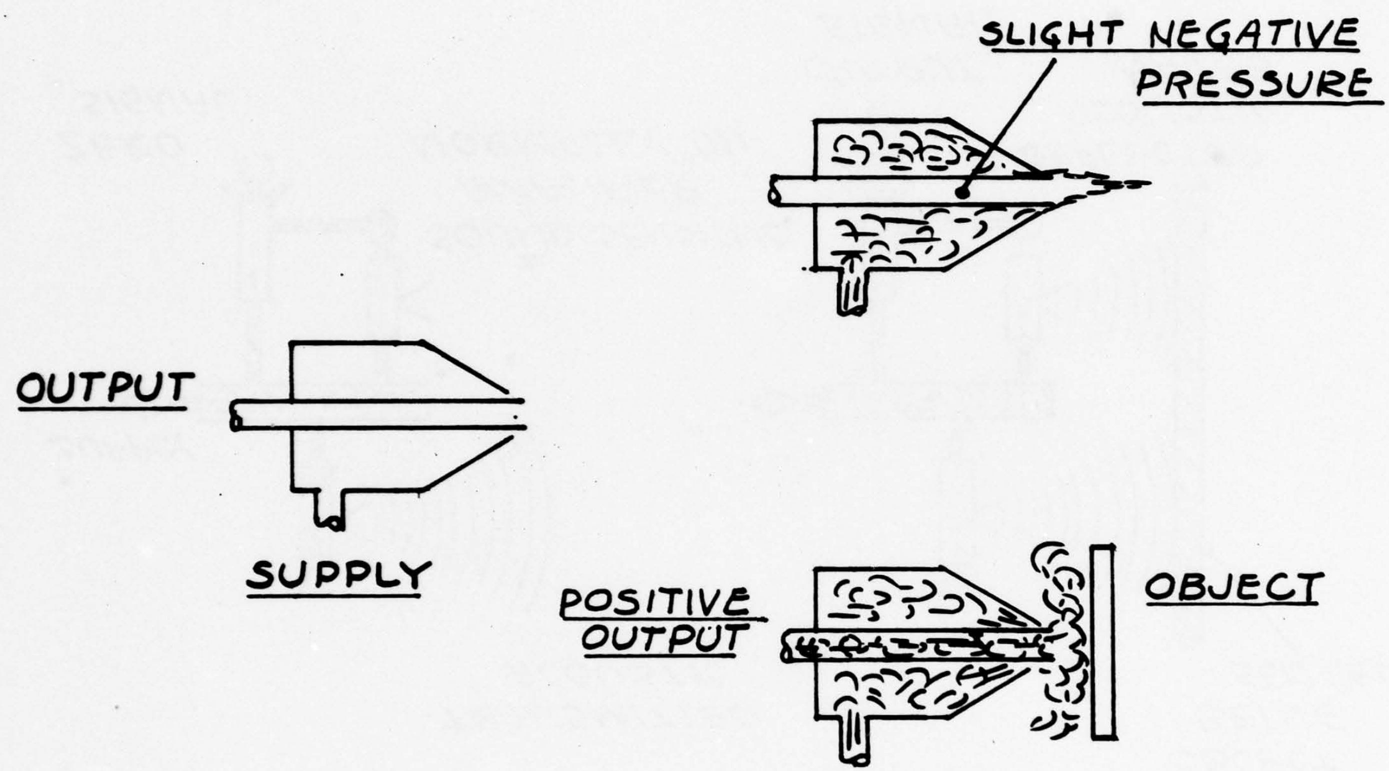

Figure 11. Proximity sensing.

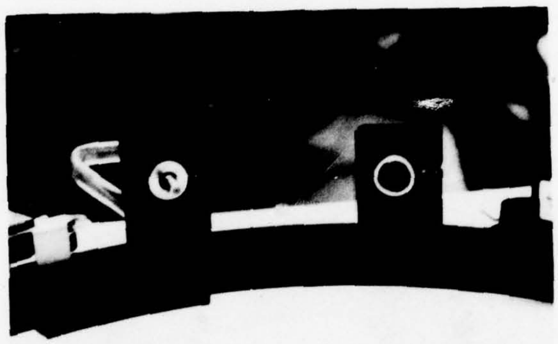

Figure 12. Proximity sensor whisker valve-sensor.

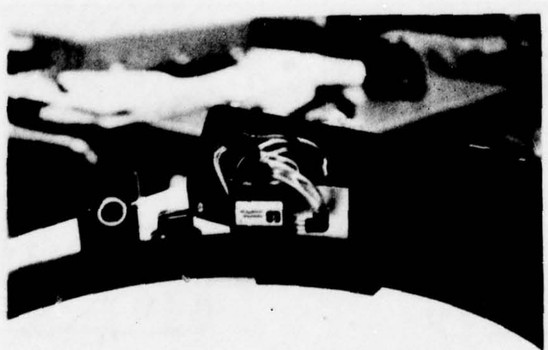

Figure 13. Whisker valve sensor double interruptible jet sensor.

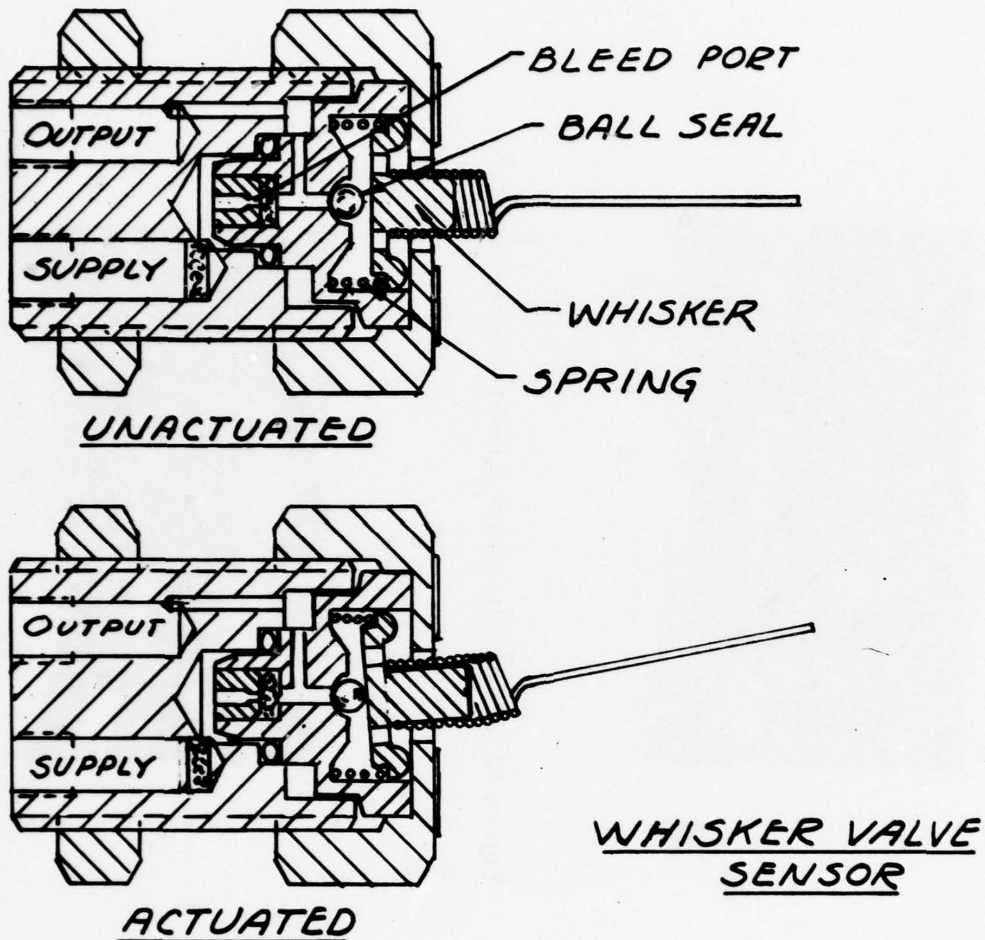

Figure 14. Whisker valve sensor.

10. The interruptible jet sensor (figs. 13,15,16) is triggered by a target which passes through the effluxing jet, momentarily blocking it. This type of sensor employs the flow movement of a fluid jet from a source to a receiver in order to effect an intelligent signal. There are many variations to this type sensor.

It should be noted that many of the sensors will appear to have speed limitations, which are due not to the sensor characteristics as much as to the fact that they are driving different output circuitry, such as the pneumatic mechanical counter. For instance, the eddy current, capacitance, and infra-red electrical sensors all have extremely fast response when driving electronic circuitry. Rapid response is also achievable with several of the fluidic sensors when they are used to drive either electrical switches or other fluidic logic circuits. The fluidic sensor's response time is measured electrically only after passage through three fluidic logic gates, where a pneumatic-to-electrical switch is activated. This can be accomplished at speeds of up to 100 Hz. The same sensor output, driving the pneumatic mechanical counter, goes through four logic elements and then to an air-piloted moving part valve. The output of the valve triggers the counter which saturates at less than 10 Hz.

INITIAL INSTALLATION

In setting up the unit, two connections must be made. The source of pneumatic power should be connected to the quick disconnect coupling which is located on the lower left side of the unit. The air supply should be as oil and dust free as possible. The inlet pressure should be regulated at a minimum of 55 psig (379 kPa) and a maximum of 90 psig (620 kPa). An electrical cable is included to allow connection to any source of 60 Hz 110 vac (fig. 17).

CONTROL PANEL

The control panel (fig. 18) has been designed with the left-hand side being electrical (fig. 19) and the right-hand side pneumatic (fig. 20). The two meters on the upper left-hand corner measure the DC voltage of the electronic power supply which powers the electronic distribution and signal conditioning circuit. The first, on the left, measures the voltage to the sensors. The second meter, on the right, indicates the DC power level which the system supplies to an auxiliary sensor. Just to the right of these meters is an electric light indicator

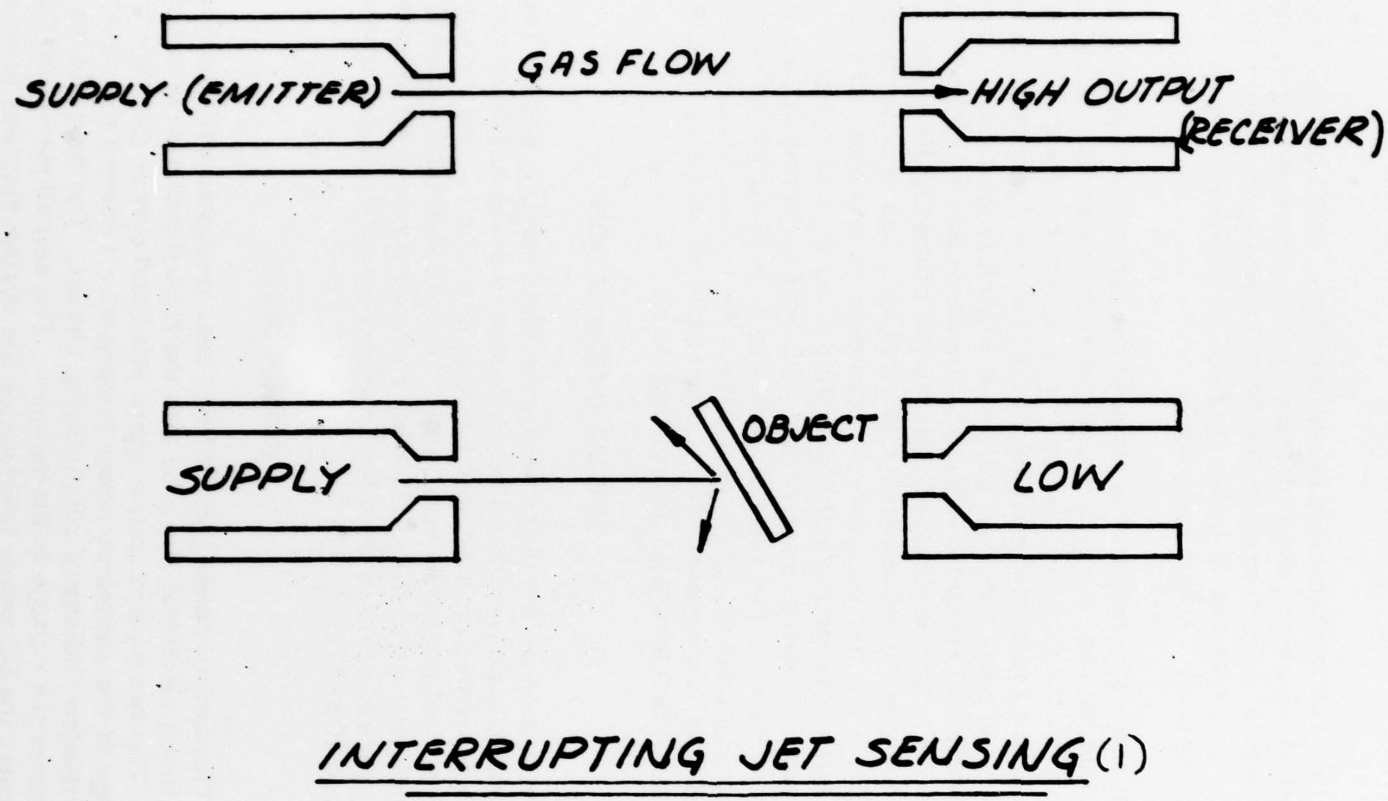

Figure 15. Interrupting jet sensing (1).

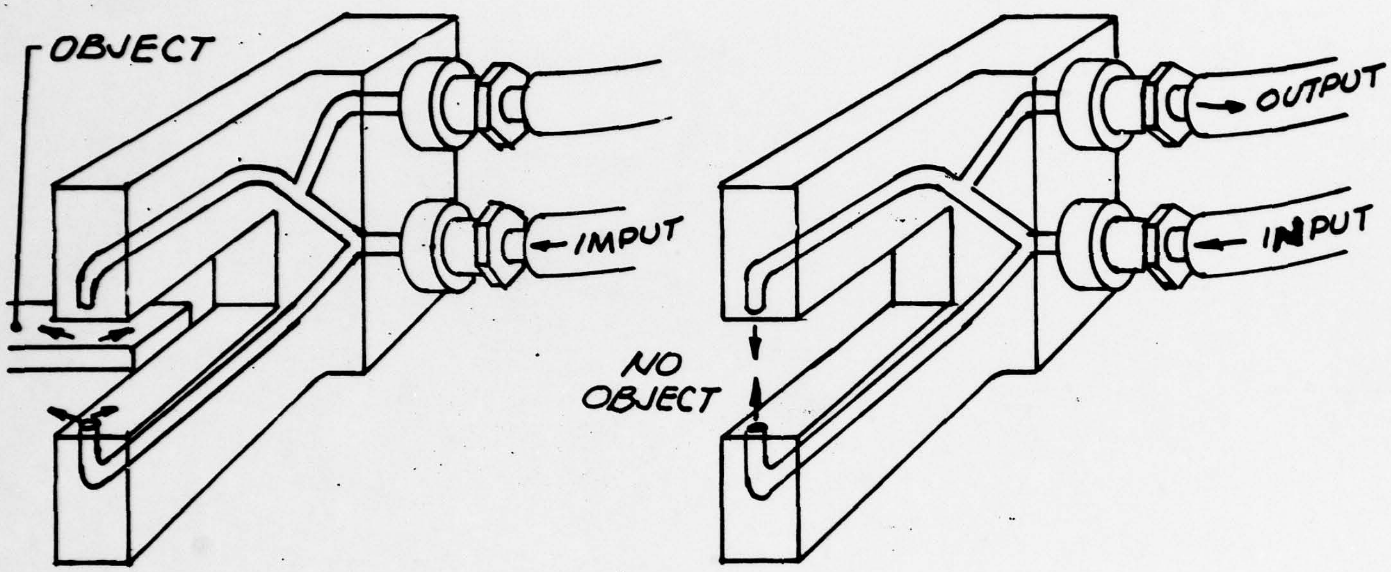

Figure 16. Interrupting jet sensing (2).

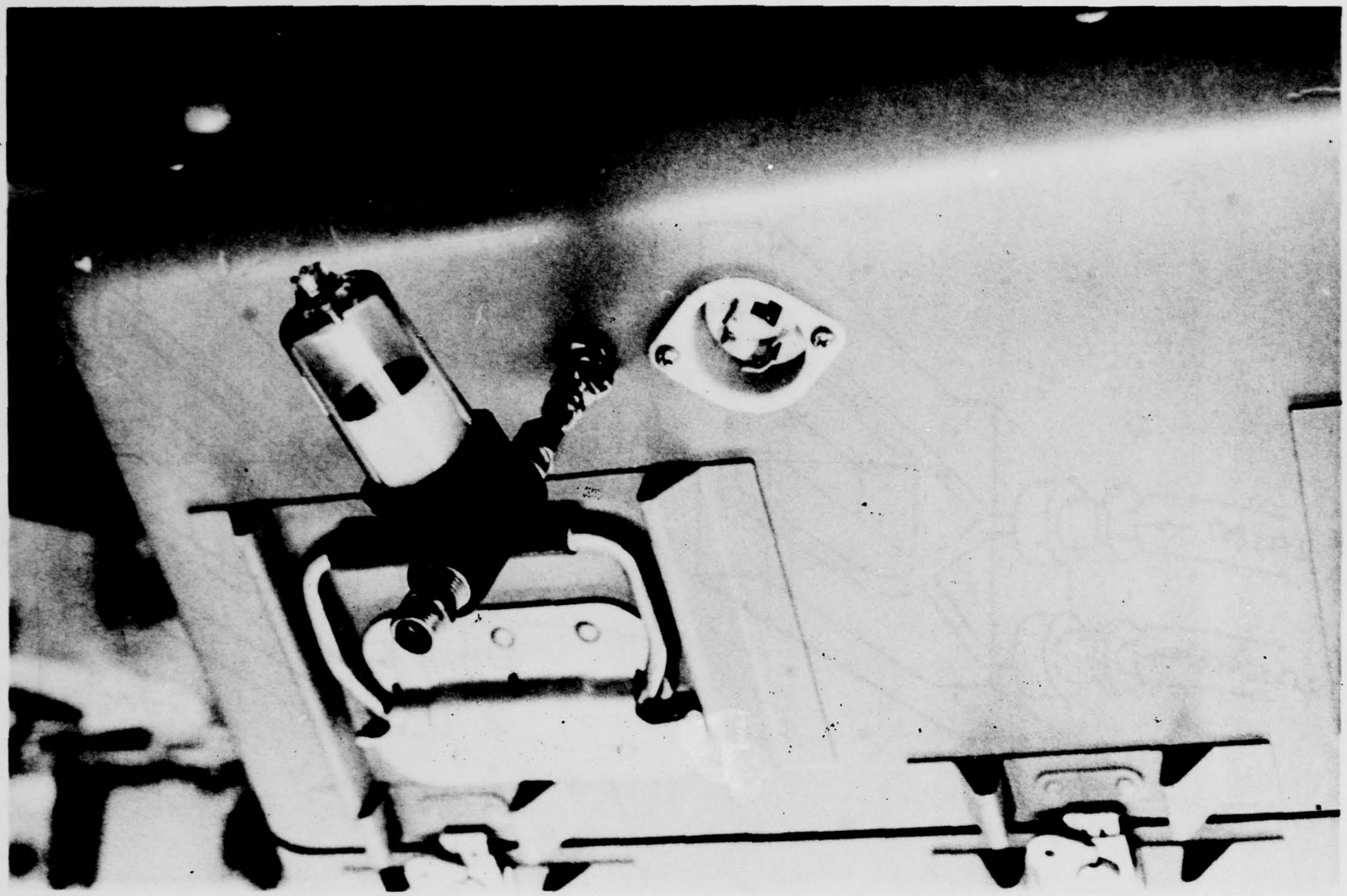

Figure 17. Control panel air and electrical connections.

Figure 18. Control panel.

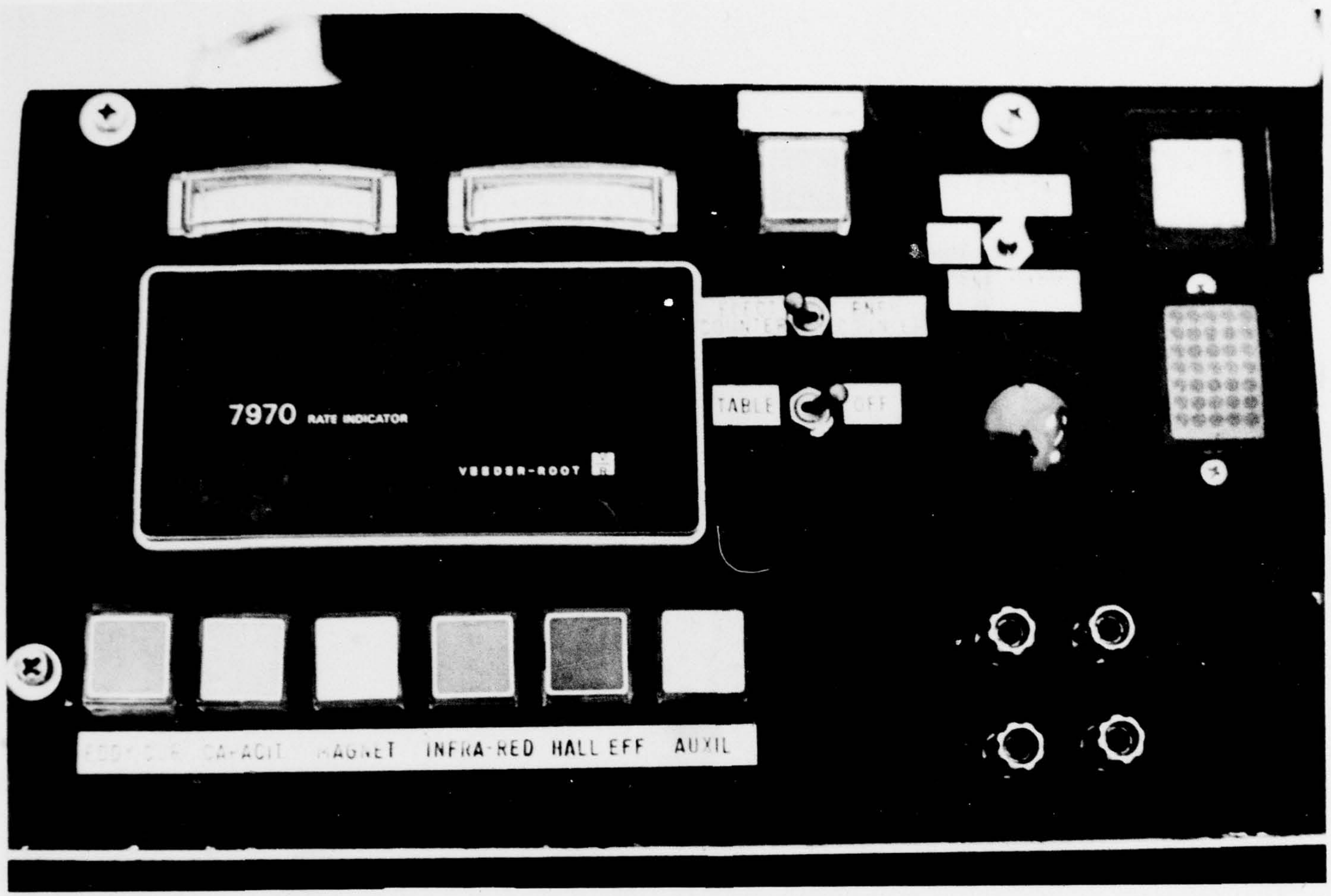

Figure 19. Control panel (left half) electrical side.

Figure 20. Control panel (right half) pneumatic side.

switch combination which provides electrical power to the control panel when pushed in and is de-energized when pushed in a second time. When energized, a light under the push button indicates that electrical power is being supplied to the control panel.

The electronic counter located just below the voltmeters is a rate measuring type and will count the number of events per unit of time. (The time base has been set at 1 second.)

There are six push buttons located beneath the counter. All are of the push-on/push-off type. Each of these provide power to a particular electronic sensor. They are arranged in the same order as the sensor array, with the first switch corresponding to the eddy current sensor and the fifth one corresponding to the Hall effect sensor. It should be noted that the system will work properly only if one electrical sensor is on at a time. The sixth switch provides auxiliary power to the upper set of terminals located at the right of the switch. The top pair of terminals is the auxiliary power, which provides 24 volts DC of output power. The bottom pair should be used to connect the auxiliary sensor's output signals to the internal logic, which is capable of reading an input level of up to 24 volts DC

At the right top center of the panel is a pneumatic power equivalent of an electric power switch which functions in a manner similar to the electric power switch, but which indicates green when "on" rather than red. It is a pneumatic push-on/push-off switch. This switch does not control pneumatic power to the board, but rather power to the pneumatic counter. Just below this indicator is an alpha indicator which has been programmed to indicate the letter "P" when pneumatic power is switched on to the pneumatic counter. A third type of pneumatic indicator (a rotating ball) located in the approximate panel center is used to indicate when the pneumatic line power has been connected to the case. It will be green, "on" when input pneumatic power is available and black in the "off" state, when input power is removed.

To the right of these indicators is a pneumatic counter. It is of the predetermined type which will count down from a preset value to zero. In order to set a value into this device, the user must lift the plastic cover and depress the reset button located to the left of the counter face. While holding the reset button down, the numerical set buttons can be pushed to effect a change in the predetermined preset value. The counter automatically resets to the preset value when it reaches zero.

At the upper right of the penumatic counter are two pressure gages. The one on the left reads the logic supply pressure and should be factory preset to 55 psi $\pm$ 5. The right-hand gauge is preset to 6.5 psi. Just below these gauges are seven pneumatic toggle valves, arranged as two rows of three plus one (fig. 20). The valves control the pneumatic power to the various pneumatic sensors with the first controlling the sonic fluidic ear. The second controls the limit valve, the third controls the proximity sensor, the fourth controls the whisker valve, and the fifth switch controls the interruptible jet sensor. The last of the six switches enables this unit to use the output of an external pneumatic sensor. The seventh switch, labelled "REMOTE POWER," turns the pneumatic supply power (55 psi) on to the upper fiting, located just below the switch. This should be connected to the remote sensor's input. The remote sensor's output should then be connected to the lower terminal.

PANEL CONTROLS

There are three electrical toggle switches which control all the signals from all the sensors to either of the counters. With the proper positioning of these switches, any of the electronic sensors can be used to drive either the electronic or the pneumatic counter and any pneumatic sensor can be used to drive either the pneumatic or the electronic counter.

One switch will automatically display the rotating table in ft/sec when switched to the left-hand "TABLE" position. It does this by reading the output of an eddy current sensor which is sensing four metal objects attached to the bottom of the rotating table. With these objects equally spaced, the counter sees one pulse for every foot of table circumference moved. Since the electric counter reads in units of events per second, its readings in the "TABLE" position correspond to ft/sec (see table 1 for proper positioning of the other switches).

Adjacent to the electronic rate indicator (counter) is a toggle switch with left and right positions labelled "ELECT COUNTER" and "PNEU COUNTER," respectively. This switch allows electrical signals from the various sensors to be directed toward either the electronic counter (rate indicator) or the pneumatic counter. For example, with the switch in the "PNEU COUNTER" position, any electronic sensor output chosen (by depressing that sensor's switch) is sent to an electronically piloted air valve (solenoid) which has a response time of about 20 ms. The output of the valve is a pulse of low pressure air which enters the pneumatic logic

Table 1. Switching diagram.

	Table	Off	ELECT Sensors	Off	PNEU Sensors	ELECT Counter	PNEU Counter	PNEU Sensor Choice	ELECT Sensor Choice	Power to PNEU Counter	ELECT Power
Measure Table Speed (ft./sec.)	X			X		X					X
PNEU Sensor on PNEU Counter		X		X			X	X		X	X
PNEU Sensor on PNEU Counter								X		X	
PNEU Sensor on ELECTR Counter		X			X	X		X			X
PNEU Sensor on ELECTR & PNEU Counter		X			X	X		X		X	X
ELECT Sensor on PNEU Counter		X	X				X		X	X	X
ELECT Sensor on Electronic Counter		X	X			X					X
ELECT Sensor on ELECT Counter and PNEU Sensor on PNEU Counter		X	X			X		X	X	X	X
PNEU Sensor on PNEU Counter and Table Rate on ELECT Counter	X			X		X		X		X	X

circuit where it then travels through four logic gates prior to activating an air piloted valve which drives the pneumatic counter. With the switch in the same position, pneumatic sensor outputs, if they are chosen, pass directly into the logic circuit, passing through the same four logic gates prior to piloting the valve which drives the pneumatic counter. The choice of which signals (electrical or pneumatic) are sent to the pneumatic logic circuit is made with the third toggle switch labelled "ELECTRICAL SENSOR" -- "OFF" -- "PNEUMATIC SENSORS".

Regardless of where the signals come from, the pneumatic counter will not accept signals unless it has been turned "on" (the green indicator visible and the alpha "P" visible). It should be noted that the pneumatic sensor's outputs are always connected to the pneumatic logic. Thus, if the user leaves one of the pneumatic sensors "on" (pneumatic toggle switch "up") and attempts to read an electrical sensor on the pneumatic counter, he will, in fact, be seeing both the electrical sensor and the pneumatic sensor on the pneumatic counter. This, of course, allows the user to operate both counters under some circumstances:

1. Electrical sensors on electrical counter

   and

   Pneumatic sensors on pneumatic counter

   or

2. Pneumatic sensors on pneumatic counter

   and

   Pneumatic sensors on electronic counter.

The air piloted valve which drives the pneumatic counter has a response time of about 10 ms; while the counter itself has a response time of 100 ms. Thus, it is not difficult to saturate the pneumatic counter especially with multiple targets. However, most of the pneumatic sensors have much better response times than the counter. One way of showing this is to use the electrical output. The pneumatic output of the sensor is propagated through the fluidic logic circuit and may be transduced to an electric signal through a pressure to the electric switch. This switch output can be read on the electronic rate sensor when the third electrical toggle switch is on "PNEUMATIC SENSORS" and the other toggle is on "ELEC COUNTER". With this condition, pneumatic signals, as fast as 100 Hz, can be measured. When the electrical sensors are used to drive the pneumatic counter, their response is limited by the counter's response. A summary of switch positions is shown in the table.

CONCLUSION

This represents the first known effórt to accomplish such a task and, as such, EMX and ARRADCOM are certain that the present effort is not all inclusive. This is due to the fact that the sensing and controls industry is very dynamic, with advances in technology occurring very rapidly. The control panel demonstrates the compatability of electronic and pneumatic technology.

Presented in this report is a cross section of the different types of sensors available in the market today. This report is considered useful to equipment system designers, as it shows advantages, disadvantages, and limitations of the various types of sensors. It may offer assistance in sensor selection for a particular application, and presents what is generally available in a condensed form.

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